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PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES INDIA

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PARTS I-II]

SECTION B

[VOL. 25

STUDIES ON THE FOOD OF SOME COMMON FISHES OF UTTAR PRADESH, INDIA

I. The Surface-feeders, the Mid-feeders and the Bottom-feeders

BY S. M. DAS AND S. K. MOITRA

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Received on October 8, 1955

(Communicated by Dr. D. R. Bhattacharya)

INTRODUCTION

THE present communication relates to the observations made on the food and feeding habits of adult food fishes of Uttar Pradesh with particular reference to their affinities to definite water levels according to their specific foods and the fauna and flora present at these levels. Such associations were also observed earlier by Mookerjee, Sen Gupta and Roy Chowdhury (1946) in Bengal, and Misra (1953) in three species of carps in U.P., but to our knowledge this is the first attempt to survey the food affinities of a majority of food fishes of Uttar Pradesh in detail. The present study is only a preliminary investigation and it is hoped that this may form the basis for a more comprehensive work on the subject.

MATERIAL AND METHODS

Weekly fish hauls were made in local tanks and ponds during the period 1953-55. Adult fishes belonging to twenty-five species were obtained. These were brought to the laboratory where they were identified, measured and weighed. The date, time and locality of the hauls were then noted.

The abdomen was then opened and the fishes fixed in 8–10% formalin for later investigations. The stomach and the intestine were carefully removed and split open and the contents washed with water into a petri-dish. The material was next examined and counted under the low and high powers of the microscope on a counting slide. The percentage composition of the gut-contents was estimated by the method followed by Hynes (1950), who in his review of methods used in the studies in the food of fishes has described the methods of estimating the percentage composition of the various organisms in the food of the fishes by the points method as followed by Swynnerton and Worthington. In this method, the percentage composition is calculated by allotting points based on their relative sizes as determined roughly under a binocular microscope by visual estimation. The points so allotted are then tabulated and the percentages calculated. After careful practice for some time it is possible to calculate the percentage values with a fair degree of accuracy. It is admitted that the percentage composition by the 'points method' is arbitrary and it provides only a rough estimate. Nevertheless in the absence of a more accurate method it gives a fair idea of the relative importance of the various food organisms in regard to the total amount of food available to the fish examined.

OBSERVATIONS

Out of the fishes examined, the food of the following eight species of food-fish (Table I), viz., *Gadusia chapra* (Ham.), *Ailia coila* (Ham.), *Catla*

TABLE I
The Percentage Composition of the Food of the Surface-feeders

Fish	Food											
	A*	B*	C*	D*	E*	F*	G*	H*	I*	J*	K*	
<i>Gadusia chapra</i>	..	47.50	10.0	23.0	0.32	11.9	0.65	6.63	..	..	..	..
<i>Ailia coila</i>	..	4.0	1.0	32.0	..	..	20.0	16.0	8.0	18.0	..	1
<i>Catla catla</i>	..	10.0	..	..	..	..	90.0	..	..	..	..	..
<i>Ambassis nassa</i>	1.0	..	..	26.7	59.9	..	..	12.4	..
<i>Ambassis ranga</i>	4.3	..	..	76.4	19.3	..	..	..	..
<i>Glossogobius giuris</i>	..	2.5	5.0	..	..	..	72.0	6.0	1.7	12.8	..	..
<i>Catlocarous pabda</i>	..	1.0	..	4.0	..	..	80.0	1.0	2.0	12.0	1.0	..
<i>Oxygaster bacula</i>	..	5.0	5.0	26.0	0.1	5.0	52.4	6.5	..	..	..	..

A*: unicellular algae; B*: multicellular algae; C*: higher aquatic plants; D*: bryozoans; E*: rotifers; F*: insects; G*: crustaceans; H*: molluses; I*: fish; J*: fish scales; K*: sand and mud.

catla (Ham.), *Ambassis nama* (Ham.), *Ambassis ranga* (Ham.), *Glossogobius giuris* (Ham.), *Callichrous pabda* Ham., and *Oxygaster bacaila* Ham., consisted of desmids (*Closterium*, *Cosmarium*), diatoms (*Cyclotella*, *Nitzchia*, *Synedra*), plankton algæ (*Volvox*, *Gonium*, *Phacus*, *Eudorina*, *Pandorina*, *Nostoc*, *Oscillitoria*, *Gleotrichia*, *Microcystis*, *Spirogyra* and *Ulothrix*), plankton rotifers (*Rotifer*, *Rattulus*), plankton crustaceans and their larvæ (*Bosmina*, *Daphnia*, *Ceriodaphnia*, *Cyclops*), and pelagic insects and their larvæ. Carp fingerling and small cyprinids were occasionally recovered from the gut contents of *Glossogobius giuris* and *Callichrous pabda*, and fish scales from *Ambassis nama*. A few small pelagic gastropod molluscs have been obtained from the gut-contents of *Glossogobius giuris* and *Callichrous pabda* on rare occasions.

Job (1940) concluded that *Therapon jerdua* was a surface-feeder due to the presence of insect larvæ and adult mosquitoes in its stomach contents. Similarly, Mookerjee *et al.*, held that fishes living at the surface-feed on crustaceans and algæ, whereas the fishes which feed on rotten plants, sand and mud are bottom-feeders. We have, however, recovered many more types of surface of planktonic food organisms from the gut contents of the fishes listed above and conclude therefore that they are surface-feeders. These fishes include both omnivorous and carnivorous forms.

Out of the fishes examined the following nine species of food-fishes, viz., *Labeo rohita* (Ham.), *Labeo bata* (Ham.), *Amblypharyngodon mola* (Ham.), *Mystus seenghala* (Sykes), *Mystus vittatus* (Bloch), *Mystus cavasius* (Ham.), *Mastacembelus armatus* (Lacep.), *Wallago attu* (Bl. and Schn.), and *Xenentodon canilla* (Ham.), had a food content (Table II) of algæ,

TABLE II
The Percentage Composition of the Food of the Mid-feeders

Fish	Food											
	A*	B*	C*	D*	E*	F*	G*	H*	I*	J*	K*	
<i>Labeo rohita</i>	..	6.3	6.6	70.6	..	0.5	0.5	1.5	..	..	..	14
<i>Labeo bata</i>	..	2.0	..	78.0	..	..	..	..	..	..	..	20
<i>Amblypharyngodon mola</i>	58.0	9.0	23.0	..	..	..	..	..	..	..	..	10
<i>Mystus seenghala</i>	..	2.0	..	..	..	98.0	..	..	..	..	..	..
<i>Mystus vittatus</i>	..	0.5	2.5	12.0	2.0	4.5	54.0	17.0	0.5	..	..	7
<i>Mystus cavasius</i>	..	1.0	1.0	4.0	..	1.0	62.4	16.0	6.0	..	6.0	8.6
<i>Mastacembelus armatus</i>	100	..	..	..	..
<i>Wallago attu</i>	100	..	..
<i>Xenentodon canilla</i>	100	..	..

(A* -K*: as in Table I.)

aquatic plants, adult crustaceans (mostly shrimps), insects and their larvæ (water-bugs, may-flies), fish (carp fingerlings, and cyprinids), fish scales and sometimes mud and sand. Occasionally statoblasts of bryozoans were recovered from the gut contents of *Mystus vittatus*. These fishes are neither true surface-feeders nor true bottom-feeders since the food organisms recovered from their gut contents are distributed more in the middle layers of the water than in the surface or bottom layers. These fishes may occasionally come up near the surface or go down to the bottom in search of their food but in the main they are mid-feeders. We therefore conclude that the above-mentioned fishes are mid-feeders since they feed essentially on sub-surface food organisms.

Out of the fishes examined the food of the remaining eight species (Table III), viz., *Cirrhina mrigala* (Ham.), *Labeo calbasu* (Ham.), *Cirrhina*

TABLE III
The Percentage Composition of the Food of the Bottom-feeders

Fish	Food											
	A*	B*	C*	D*	E*	F*	G*	H*	I*	J*	K*	
<i>Cirrhina mrigala</i>	..	10.0	7.5	72.5	..	..	..	..	..	..	..	10
<i>Cirrhina reba</i>	..	20.0	7.0	52.0	..	1.0	..	..	..	..	..	20
<i>Labeo calbasu</i>	..	6.5	6.0	65.0	..	6.0	..	..	..	..	..	17
<i>Puntius sarana</i>	..	8.0	..	72.0	2.0	..	8.0	2.0	8.0	..	..	..
<i>Puntius sophore</i>	..	4.0	9.5	30.2	4.0	11.0	45.0	17.8	..	..	..	19
<i>Rohtee cotio</i>	..	6.0	2.0	20.0	24.5	7.0	16.0	17.0	..	..	..	7.5
<i>Ophicephalus striatus</i>	1.5	..	..	48.0	..	..	50.5	..	..
<i>Rita rita</i>	20.0	..	75.0	..	..	..	..

(A*-K *: as in Tables I and II.)

reba (Ham.), *Puntius sarana* (Ham.), *Puntius sophore* (C. and V.), *Rohtee cotio* (Ham.), *Ophicephalus striatus* Bloch, and *Rita rita* (Ham.), consisted of algae, decomposed aquatic plants (*Vallisneria*, *Hydrilla* and *Salvinia*), bryozoans and their statoblasts (*Plumatella*, *Pectinatella*), molluscs (*Vivipara bengalensis*, *Lamellidens* sp.), fish (carp fingerlings and cyprinids), fish scales, and large quantities of sand and mud. Bottom crustaceans were frequently present in the gut contents but not the pelagic cladocera and copepods.

Bapat and Bal (1950) included *Herengula punctata* and *Nematolosa nasus* among the bottom-feeders as mud and sand were found in large quantities

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in their stomachs. But, besides large amounts of sand and mud, we have also recovered many types of bottom-dwelling forms like bryozoans and molluscs, in the gut contents of the fishes listed above, as also decomposed aquatic vegetation. From these observations we conclude that these fishes are bottom-feeders, and they contain herbivorous, omnivorous and carnivorous forms.

It will be interesting to note that the surface-feeders are both omnivorous and carnivorous; the mid-feeders, herbivorous and carnivorous; and the bottom-feeders, herbivorous, omnivorous and carnivorous. Apparently competition for food is the greatest in the bottom layer of the water bodies while there is almost equal competition in the surface and middle layers. The food in these three levels of water is not uniform throughout the year, but varies in the different seasons. We have found that the herbivorous and the carnivorous fishes always show definite peak periods in feeding, while the omnivorous ones show little variation throughout the year. This is probably so because phytoplankton and zooplankton have an inverse ratio in their abundance during the year as shown by Das and Srivastava (1955). This signifies that if one kind of food is less the other is present in larger amounts for the fish to have normal feeding.

CONCLUSIONS

On the basis of the gut content analysis, the food fishes of Uttar Pradesh have been broadly divided into three groups, the surface-, the mid-, and the bottom-feeders. The surface-feeders feed on surface plant and animal organisms, the mid-feeders feed on sub-surface food organisms, and the bottom feeders feed on bottom fauna and flora.

SUMMARY

By careful examinations for over two years of the stomach contents of adult food-fishes of Uttar Pradesh it was possible to decide which of them were surface-feeders, which mid-feeders and which bottom-feeders.

The food of the surface-feeders mainly consisted of plankton algae, plankton rotifers, plankton crustaceans and their larvae. The fishes belonging to this group are *Gadusia chapra* (Ham.), *Ailia coila* (Ham.), *Catla catla* (Ham.), *Ambassis nama* (Ham.), *Ambassis ranga* (Ham.), *Glossogobius giuris* (Ham.), *Callichrous pabda* Ham., and *Oxygaster bacaila* Ham.

The food of the mid-feeders was found to consist of algae, aquatic plants, adult crustaceans, insect, fish and fish scales, and mud and sand. The fishes belonging to this group are:—*Labeo rohita* (Ham.), *Labeo bata* (Ham.),

Amblypharyngodon mola (Ham.), *Mystus seenghala* (Sykes), *Mystus vittatus* (Bloch), *Mystus cavasius* (Ham.), *Mastacembelus armatus* (Lacep.), *Wallago attu* (Bl. and Schn.), and *Xenentodon canilla* (Ham.).

The food of the bottom-feeders consisted of decomposed aquatic vegetation, bryozoans and their statoblasts, insects, crustaceans, molluscs, fish and fish scales, sand and mud. The fishes belonging to this group are:—*Cirrhina mrigala* (Ham.), *Cirrhina reba* (Ham.), *Labeo calbasu* (Ham.), *Puntius sarana* (Ham.), *Puntius sophore* (C. and V.) *Rohita cotio* (Ham.), *Ophicephalus striatus* Bloch, and *Rita rita* (Ham.).

ACKNOWLEDGEMENTS

The authors wish to acknowledge their gratitude to the Scientific Research Committee, U.P., but for whose help the present studies would have been impossible and also to the authorities of the Lucknow University for research facilities.

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ON THE ORIGIN OF POLYOVULAR FOLLICLES IN THE OVARY OF *SEMNOPITHECUS ENTELLUS*

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Received on August 18, 1955

INTRODUCTION

DURING studies on the cytoplasmic inclusions in the oogenesis of *Semnopithecus entellus* (the Himalayan Langoor) stages in the development of polyovular follicles of the ovary were observed. The present paper describes three modes of the origin of polyovular follicles from the uniovular ones, as observed in *Semnopithecus entellus*. Maximum number of four ova in one follicle has been noticed. Polyovular follicles have been described by previous workers in mammals but they have failed to notice the detailed processes of the formation of the polyovular follicles.

MATERIAL AND METHOD

The material for the present study was obtained by shooting "Himalayan Langoors" round about Mukteswar, a place situated at a height of about eight thousand feet in the Kumaun Himalayas. Small pieces of the ovary were fixed in Bouin, Susa and Shridde fixatives. Sections from the material fixed in Bouin and Susa were stained by Mann's methyl blue eosin while Shridde's sections were stained by Iron-alum-hæmatoxylin.

THE POLYOVULAR FOLLICLES

In the stroma of the ovary, polyovular follicles have been observed which arise from the uniovular follicles by three distinct processes.

(1) In some cases, follicular cells get arranged in a single layer around small oocytes. Then partition walls are laid down in different angles, resulting in the unequal divisions of the primary oocyte. The resulting picture of all these changes is a polyovular follicle with 3 or 4 oocytes. (Pl. I, Figs. 1-4).

(2) In other cases, the follicular cells seem to play an important part in the division of the primary oocyte. In the initial stages few follicular cells come to surround the primary oocyte which is followed by a definite arrangement of the follicular cells in a single layer. As the oocyte grows there appears a dividing line on its sides. Along this dividing line follicular

cells invade the primary oocyte and this process goes on till the follicular cells are successful in separating the original oocyte into two daughter ones. Later on definite cell-walls are laid down around the two daughter oocytes. In this way polyovular follicles with 2 or 3 oocytes result (Pl. I, Figs. 5-8).

(3) The third mode of origin of polyovular condition is unique and provides some interesting features. During the initial stages of this process we find proliferation of the follicular cells on one side of the primary oocyte, resulting in a bulging mass. Later on some of the follicular cells from this mass gets dissolved out which result in the appearance of a vacuole. This clear space goes on enlarging till it finally touches the zona pellucida of the original oocyte. The wall of the original oocyte gets dissolved out and then there is free communication which facilitates the transfer of the protoplasmic and the nuclear material from the primary oocyte to the developing oocyte. At this stage the appearance of the nucleus and cytoplasmic inclusions on the side adjacent to the primary oocyte leave little doubt that they must have come from the primary oocyte as a result of amitotic division. Later on definite cell-wall is laid down around the secondary oocyte and then the two oocytes come to lie separately surrounded by the follicular cells. All these stages result in a polyovular follicle (Pl. II, Figs. 9-12).

DISCUSSION

It has been known for some time that a polyovular condition precedes the formation of twins, triplets, quadruplets, quintuplets in many mammals occasionally and in some mammals generally. The Langoor (*Semnopithecus*) in a very highly evolved mammal and the polyovular condition described in the present paper, is, to my knowledge, the first definite demonstration of 3 modes of the formation of polyovular follicles in higher mammals. This is still more interesting on account of the possibility that this phenomenon may be applied to man as well.

Baker,¹ in his masterly review on the cell theory has established 3 modes of cell multiplication, e.g., Exogeny, Endogeny and cell partitioning. The three modes observed by me fit into his classification in as much as the modes (1) and (2) described by me are related to his cell division by partitioning. But my mode (3) is not the exogeny by vacuolation as described by Baker. Not only is the newly one vacuole formed outside the cell, but there is a migration of the protoplast of the oocyte into the vacuole. This may be termed as the fourth category of exogeny, besides the 3 mentioned by Baker, and I suggest the name "Exogeny with vacuolation—migration of protoplast".

The present paper also shows for the first time the importance of the follicular cells in the production of polyovular follicles in mammals. The polyovulry, resulting as a result of the processes described above is responsible for multiple ovulation. Mostly, previous workers have shown that multiple ovulation is due to discharge of more than one ova at one time from different follicles but the occurrence of polyovular follicles in *Semnopithecus cutellus* leave little doubt about the possibility of simultaneous discharge and consequent fertilisation of more than one ova from the same follicle. This phenomenon accounts for the formation of twins, triplets and quadruplets, etc., in the present case. Here it will not be out of place to mention about the distinction of twins into true and false twins drawn by Arey.² He calls dizygotic twins, produced as a result of fertilisation of two different ova, as false twins or members of the same litter. According to him true twins are derived from a single egg whereby each member acquires the same chromosomal and cytoplasmic constitution. If this is accepted then offsprings of *Simnopithecus entellus* will be members of the same litter (false twins).

No doubt these observations are different from the case of *Dasypodina aramadillos* where development of more than one "organising centres" help in the production of quadruplets. It will be interesting to note that the formation of "polyplets" in human beings may be resulting by similar modes of polyovulry, since the "Langoor" is also a very highly evolved primate.

ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to Dr. S. M. Das, Reader in Zoology, University of Lucknow, for suggestion and discussion of some of the points raised in this paper.

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2. AREY, L. B., 1947, *Development Anatomy*, Saunders Company, Philadelphia, 170-71.

LETTERING

P.O. ..	Primary oocyte.
F.C. ..	Follicular cells.
C.S. ..	Clear space.
S.O. ..	Secondary oocyte.
Pr.F. ..	Proliferation of follicular cells.

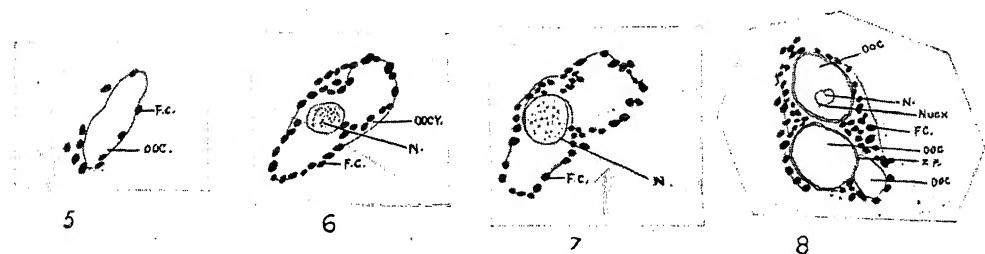
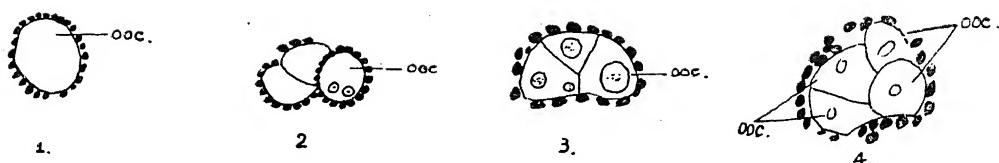
EXPLANATION OF PLATES

PLATE I (Camera lucida drawings)

FIGS. 1-8. Figs. 1-4. Stages in the development of a polyovular follicle with four oocyte from the primary oocyte by simple partition walls (Shridde Method; iron-alum-hæmatoxylin), 10×90 . Fig. 5. A developing oocyte surrounded by few follicular cells (Shridde method; iron-alum-hæmatoxylin), 10×90 . Fig. 6. Showing definite arrangement of the follicular cells around the developing oocyte (Shridde method; iron-alum-hæmatoxylin), 10×90 . Fig. 7. Showing invasion of the follicular cells at two spots on the side of the developing oocyte (Shridde method; iron-alum-hæmatoxylin), 10×90 . Fig. 8. A polyovular follicle with three distinct oocytes produced as a result of the invasion of the follicular cells (Shridde method; iron-alum-hæmatoxylin).

PLATE II (Microphotographs)

FIGS. 9-12. Fig. 9. Section showing a primary oocyte (P.O.) and the proliferation of the follicular cells (Pr.F.) (Shridde method; iron-alum-hæmatoxylin), $\times 250$. Fig. 10. Section showing appearance of a clear space (C.S.) in the follicular cells of the primary oocyte (Shridde method; iron-alum-hæmatoxylin), $\times 260$. Fig. 11. Section showing the clear space (C.S.) touching the primary oocyte (Shridde method; iron-alum-hæmatoxylin), $\times 250$. Fig. 12. Section showing the primary oocyte (P.O.) with the nucleus (Nuc.) and the secondary oocyte (S.O.) with the nucleus (Nuc.S.) enclosed by the follicular cells (Shridde method; iron-alum-hæmatoxylin), $\times 250$.



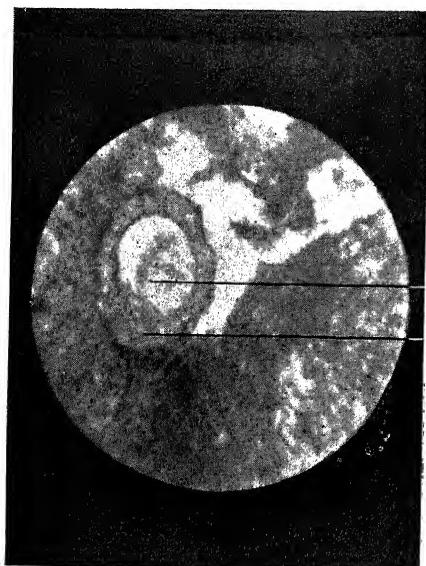


FIG. 9

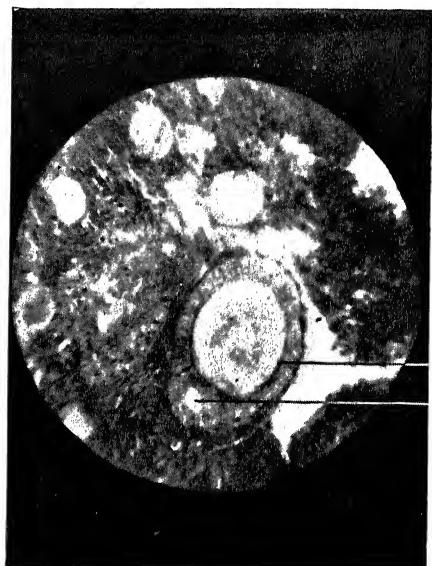


FIG. 10

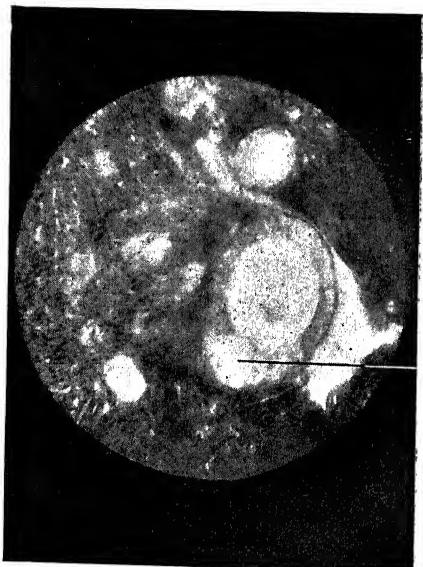


FIG. 11

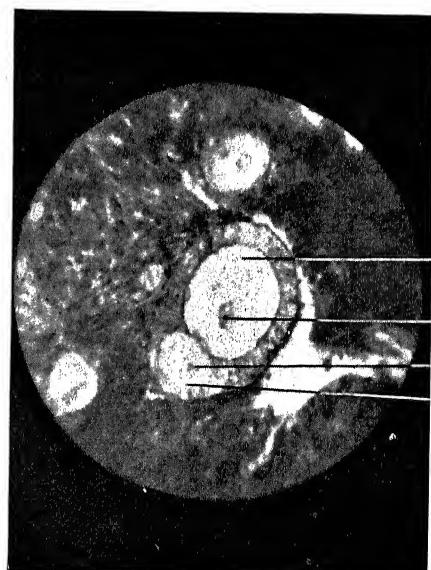


FIG. 12

STUDY OF VARIATION IN *PESTALOTIA* *MALORUM* AND *P. PSIDII*

BY M. P. TANDON

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Read on December 28, 1954

THE concept that physiological differences exist between the members that together constitute a given species of fungus probably has its origin in bacteriology. In the early years of bacteriology there were two opposing schools of thought, one of which held to the monomorphic hypothesis and the other to the polymorphic hypothesis. Adherents of the monomorphic hypothesis believed in fixity and immutability of species, while followers of the polymorphic hypothesis, on the other hand, believed in variability in morphological and physiological characteristics.

It is observed that when any fungus is grown on synthetic media, it produces a number of isolates which differ amongst themselves. Even though the differences may be so minute as to be morphologically indistinguishable, they are nonetheless real and may be of considerable importance.

Several terms including 'Variation,' 'Mutation' and 'Saltation' have been more or less loosely used in connection with the phenomenon of differences amongst the members that comprise a given species of fungi. 'Variation' is applied to divergences whether morphological or physiological from the observed characteristics of the usual or normal condition. They are regarded as non-hereditary. 'Mutation' as originally employed by de Vries, refers to sudden variations, the offspring differing from the parents in one or more clearly defined characteristics. Mutation is to be distinguished from gradual variation such as may occur during the course of countless generations. Furthermore, mutations are hereditary, since once they appear they can be transmitted to the progeny. 'Saltation' may be defined as a type of mutation that appears in artificial cultures. Saltations may be maintained indefinitely in sub-cultures if conidia or hyphæ used for transplantation are prevented from admixture.

The differences in cultural characteristic as for example, colour of mycelial mat, shape of colonies, surface markings, size of colonies, branching of hyphæ and abundance of conidia are employed to distinguish different strains of fungi. On the basis of such differences Christiansen (1932) was able to isolate 15 races of *Pestalozzia funerea* from needles of long leaf pine.

Variations in spores have been observed in *Pestalotia* sp. also. The genus has been reported to produce aberrant spores and in the course of various investigations on *P. psidii* and *P. malorum* they were observed by the writer also. La Rue and Bartlett (1922) were unable to find any strain constant for any morphological aberrances of the natural type. It was, therefore, considered desirable to study the behaviour of aberrant spores of *P. malorum* and *P. psidii*.

MATERIAL AND METHODS

P. malorum and *P. psidii* were cultured in plates containing Asthana and Hawkers medium A. After sporulation the plates were examined for normal 4-septate spores as well as for spore aberrances which consisted of uni- or bicelled spores. Monospore culture of unicelled, bicelled and 4-septate spores of both *P. malorum* and *P. psidii* were grown in plates and they were designated as the first generation. An inoculum from the first generation to fresh plates containing medium A gave rise to the second generation. In this manner three generations each of unicelled, bicelled and 4-septate spores were prepared for both the organisms. All the cultures were maintained at 18–20° C.

OBSERVATIONS

When the organisms had sporulated, a number of slides of every variant for each generation were prepared and examined. The results are tabulated in Table I.

TABLE I
Gives the Percentage of Different Types of Spores Produced by 3 Generations of P. malorum and P. psidii

Monospore culture	Genera-tion	Type of spores produced by					
		<i>P. malorum</i>			<i>P. psidii</i>		
		4-septate %	bi-celled %	Uni-celled %	4-septate %	bi-celled %	Uni-celled %
Unicelled spores (Aberrant form)	..	1	91.3	3.5	5.2	94.2	3.2
	..	2	93.6	2.8	3.6	92.5	2.7
	..	3	92.7	3.0	5.3	93.0	3.1
Bicelled spores (Aberrant form)	..	1	92.4	3.6	4.0	91.8	3.6
	..	2	95.3	2.2	2.5	93.8	2.5
	..	3	96.0	2.6	1.4	92.7	3.3
4-septate spores (Normal type)	..	1	94.2	2.8	3.0	95.6	1.3
	..	2	96.7	1.6	1.7	97.4	..
	..	3	93.5	2.0	4.5	94.1	1.5

From the above table it is observed that in spite of the fact that monosporic cultures of unicelled, bicelled and 4-septate spores were raised they all developed a colony where 4-septate spores predominated in every generation. It further showed that aberrant spores were capable of producing normal progeny and normal 4-septate spores produced progeny that contained aberrant spores.

DISCUSSION

The genus *Pestalotia* has unique spore characters which clearly distinguish it from all other genera of fungi. Production of aberrant spores is a common feature of this genus and has been reported by La Rue and Bartlett (1922) and Guba (1929, 1932). It was noticed that both *P. malorum* and *P. psidii* produced aberrant forms which looked like single and bicelled spores. Normally when a culture originates from a single conidium it is regarded as clonal and is presumed to be genetically pure. It was, therefore, considered desirable to study whether the organisms were constant for morphological aberrances of the natural type or not. The present investigation clearly revealed that in spite of the fact that monosporic cultures of both aberrant and normal spores were raised they always produced a number of types of spores. Variations occurred in the colonies and in every case the normal type—4-septate spores predominated. La Rue (1922), carried out an investigation on the effect of selection within pure vegetative lines on *P. guepini*. He could not obtain evidence to show that selection had been effective in raising a progeny that did not vary from the parent form. Christiansen (1932) made similar observations for *P. funerea*.

Variations in different generations or subsequent progenies were not so marked as in every case only 4-septate spores, viz., the normal type predominated. It must, however, be admitted that minor variations were quite evident. According to Wolf and Wolf (1947) the differences may be so minute as to be morphologically indistinguishable. They are nonetheless real and are of tremendous importance. According to them the problems of virulence of species, of their aggressiveness, of the outbreak of epidemics, and of the breeding of crop plants that were resistant or immune to attack, all hinged on the fact that such differences were meaningful and they must be taken into account.

SUMMARY

P. malorum and *P. psidii* have been observed to produce aberrant spores which are either unicelled or bicelled.

A study of the monosporic cultures of aberrant spores and normal 4-septate spores for three generations brought out the fact that in every case the normal type, *viz.*, only 4-septate spores predominated and every culture had various amounts of other types of spores. Thus it was not possible to raise a pure line progeny of either aberrant spores or normal 4-septate spores.

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TWO NEW SPECIES OF STRIGEID CERCARIÆ FROM NORTHERN INDIA

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INTRODUCTION

IN previous communications dated 1951, 1952 and 1953 seven strigeid cercariæ infesting the common Indian snail *Indoplanorbis exustus* were described by me. In this paper two more new species of holostome cercariæ, *Cercaria soraonensis*, n. sp. and *Cercaria kumari*, n. sp. occurring in *Lymnaea luteola* f. *australis* are described. The two new species are pharyngeal, longifurcate, distomate without eye spots and have transverse rows of body spines, four penetration glands back of ventral sucker many caudal bodies on the tail and develop in long thread-like sporocysts.

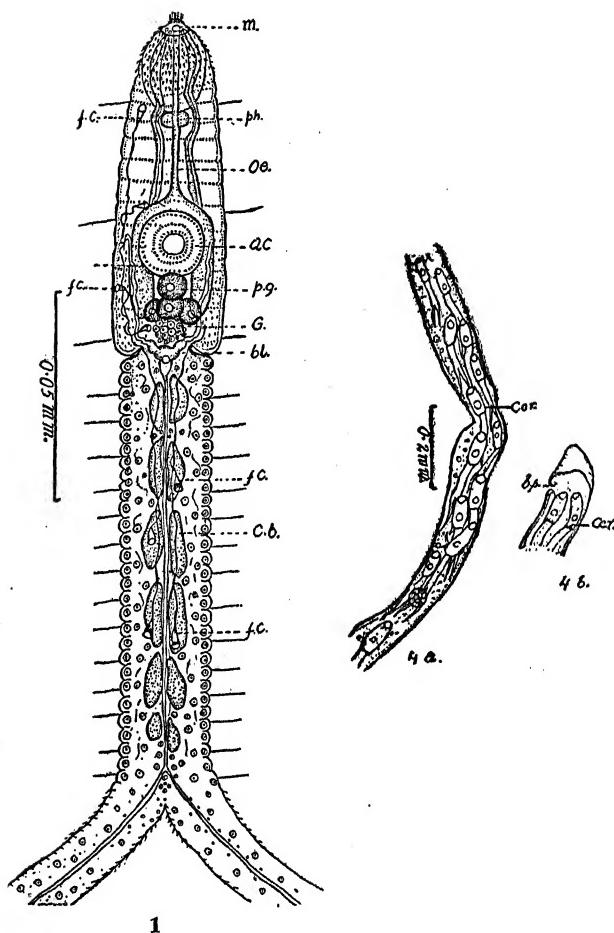
A detailed account of the structure and activity of these two forms and their possible relations with other Strigeid cercariæ as well as the general discussion of the group to which they seem to belong is given.

Cercaria soraonensis, n. sp.

(Figs. 1, 4 a and 4 b)

In a collection of 78 *Lymnaea luteola* f. *australis* from a small pond near Rithaian, a village in Allahabad in April 1953, one snail was found to discharge this species of cercariæ in large numbers. The infected snail was kept alive for about 20 days which gave a good opportunity to study this form in much detail.

The cercariæ of this species appear to emerge from the snail host continuously but more abundantly during the day than in the night. The observations on their behaviour and activity agree with previous accounts. In undisturbed water the cercariæ hang motionless with body downward and the furcae forming an angle of about 90° to the tail-stem which remains well extended. They gradually sink from time to time. Sinking cercariæ shoot upward with a characteristic wriggling movement to a height several times their body length and again take their original position. The period of rest is longer than the period of active swimming and after a short free existence



TEXT-FIGS. 1. 4 a and 4 b.—Fig. 1. *Cercaria soraonensis* showing details of structure. Fig. 4 a. A portion of the sporocyst of *C. soraonensis*. Fig. 4 b. Anterior end of a sporocyst.

a.c., Acetabulum; bl., Bladder; C., Intestinal cæca; c.b., Caudal bodies; Cer., Cercarids; f.c., Flame cells; G., Genital primordium; g.b., Germ balls; m., Mouth; p.g., Penetration gland; ph., Pharynx.

most of the larvae are found to move on the bottom of the vessel by the aid of anterior organ and the ventral sucker.

The body is much flattened posteriorly and narrow anteriorly and very flexible in the living condition. Striking constrictions appear in the pre-acetabular region when it is subjected to cover glass pressure.

Cercariæ, killed by adding four parts of hot 10% formalin to one part of tap water are well extended and uniform in size and shape. Measurements of such specimens are given in millimeters and averages are for

measurements of ten specimens. Body 0·161–0·165 (av. 0·16) long; 0·046–0·056 (av. 0·049) wide; Tail-stem, 0·184–0·207 (av. 0·192) long; 0·032–0·036 (av. 0·034) wide. Furcæ, 0·161–0·193 (av. 0·184) long and 0·0138–0·023 (av. 0·015) wide at the bases.

The anterior penetration organ is from pyriform to oval in shape and measures 0·032–0·041 (av. 0·036) in length and 0·023–0·027 (av. 0·025) in breadth. The extreme anterior tip of the anterior organ is produced into a retractile snout provided with 3–4 rows of thick, shining spines directed anteriorly. Behind these rows of spines the cuticula of body is provided with fine spines arranged in transverse rows upto the level of the acetabulum. Behind the acetabulum the body contains sparsely and irregularly distributed spines extending upto the posterior end.

The large and muscular acetabulum is situated at about the middle of body and has a circular opening in the centre. It measures 0·032 mm.–0·036 mm. in diameter and bears 3–4 rows of spines. The mouth is terminal and leads to a globular pharynx placed just behind the posterior margin of the anterior penetration organ. The large narrow œsophagus bifurcates anterior to the acetabulum and the relatively large and wide intestinal cæca end in level to the second pair of penetration glands.

The tail-stem contains six pairs of caudal bodies supported by strands of connective tissue and take no stain with neutral red. The two rows of nuclei on either side of the tail-stem and also about 14 long sensory hairs characteristic of many species are present (Fig. 2). The furcæ are nearly as long as the tail-stem and have fine spines at their bases.

The penetration glands are four and back of ventral sucker. Each cell is rounded and provided with a distinct nucleus in the centre. The glands of the first pair are in a line whereas the other two lying opposite each other constitute the second pair. The ducts of these glands open two on each side of the mouth.

The excretory system is devoid of any transverse commissure in the body; the two arms of the bladder divide into anterior and posterior collecting ducts. Each of the anterior collecting duct join two flame cells whereas each of the posterior duct after receiving capillaries from two flame cells in the posterior region of body extend in the tail to end in two flame cells. The caudal excretory duct originates from the posterior end of the bladder through an 'Islet Aperture' and forks at the distal end of the tail and the resulting tubes open at about half the length of the furcæ.

The genital primordium lies in front of the bladder behind the last pair of penetration glands. It is composed of small rounded cells with clear nuclei.

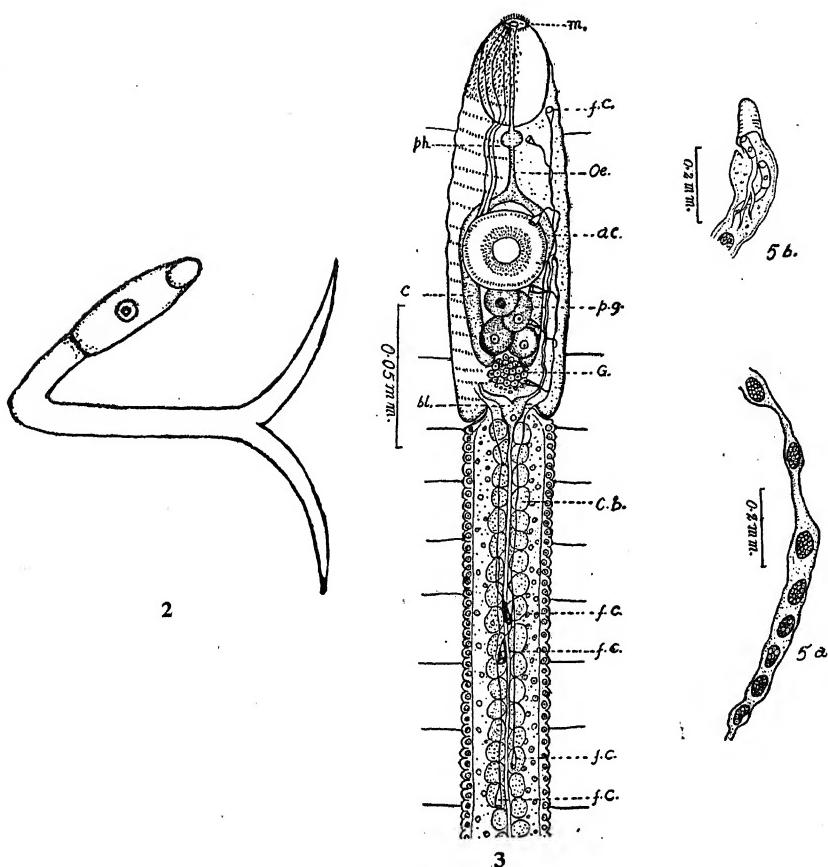
The liver of the snail host is heavily infested with masses of entangled sporocysts with their anterior ends protruding from the general surface of the liver. The rest of the body is buried deeply in the liver tissue. The sporocysts perform independent worm-like movements. They show an uniform width with few constrictions at places. They measure 0·5 mm.-0·6 mm. in length and 0·05 mm.-0·1 mm. in breadth. The anterior end which is produced into a snout-like structure contains the birth pore and birth canal (Fig. 3).

Cercaria kumari n. sp.

(Figs. 2, 3, 5 a and 5 b)

The cercaria was found in three out of 213 *Lymnaea luteola* f. *australis* collected from the same locality as *C. soraonensis*, n. sp. in April 1953. The cercariæ of this species emerge in large numbers so that the water of the container becomes almost dense with them. Their free life is divided between periods of rest when most of the larvae remain suspended for some time and periods of activity when numbers of cercariæ are observed swimming forth and back in the medium. The position of the larva during few short periods of rest and as shown in Fig. 4 is similar to that of the cercariæ of *Diplostomum flexicaudum* (Cort and Brooks, 1928, Van Haitsma, 1931). During this period the tail-stem is bent so that the body and first fourth of the tail-stem form an angle with the rest of the tail; while the furcae being held at about 60° to the tail-stem. Cercariæ swim both backward and forward with the vibration of the body and tail. Since they swim on their long axis, they take a spiral course, and therefore, wander all round through the water. In living cercariæ the body exhibits six annulations beginning behind the oral sucker and extending upto the anterior margin of the acetabulum. These annulations are probably caused by the contraction of circular muscle bands. In the extended condition small posteriorly directed spines cover the anterior portions of body upto half the level of the anterior penetration organ, except at the extreme tip where there is a circumoral spineless area. Behind these the body spines are arranged in definite rows extending upto the posterior end, the terminal row being at the level of the excretory bladder. Each row is composed of smaller spines than those of the anterior end.

The measurements of 10 specimens fixed in 10% hot formalin are:
Body length 0·23 mm.-0·26 mm. (av. 0·25 mm.), body width 0·05 mm.-



TEXT-FIGS. 2, 3, 5 a and 5 b. Fig. 2. *Cercaria kumarii* showing resting state in water. Fig. 3. *Cercaria kumarii* showing details of structure. Fig. 5 a. A portion of the sporocyst of *C. kumarii*. Fig. 5 b. Anterior end showing birth pore.

0·06 mm. (av. 0·06 mm.), tail-stem length 0·3 mm.–0·33 mm. (av. 0·32 mm.), tail-stem breadth 0·03 mm.–0·04 mm. (av. 0·03 mm.), furcal length 0·3 mm.–0·33 mm. (av. 0·32 mm.). The anterior organ is oval, larger than the acetabulum and measures 0·06 mm.–0·067 mm. (av. 0·064 mm.) in length and 0·033 mm.–0·046 mm. (av. 0·036 mm.) in width. The digestive system is well developed. The pharynx is well developed, globular, the œsophagus long, intestinal cæca prominently developed reaching almost to the posterior end of the body. The acetabulum with a circular opening has three rows of spines on its surface. It measures 0·046 mm.–0·053 mm. (av. 0·051 mm.) in diameter.

The penetration glands are four, back of ventral sucker and their ducts lead anteriorly through the oral sucker to open in groups of two at each

lateral margin of the circumoral spineless area. Posterior to the penetration glands there is a compact mass of small cells representing the analage of the genital complex.

The tail of the cercaria is longer and slightly narrower than the body. It has 20 pairs of small caudal bodies attached to its central core by fine strands of tissue. The surface of the tail-stem is very finely annulated and bears about 7-8 distantly placed sensory hairs. Such hairs two on each side are also present on the body. The furcae are as long as the tail and bear fine spines at their bases. There are six pairs of flame cells in the body; three pairs in the anterior and three in the posterior part *plus* two cells well back in the tail-stem on each side of the caudal excretory duct. The bipartite excretory bladder having an "Island of Cort" is at the most posterior part of the body. The caudal excretory duct originating from the bladder runs through the centre and bifurcates at the level of the furcae and each branch proceeds in a furca to empty by a minute pore in the middle.

The sporocysts of *C. kumari*, n. sp. are long slender thread-like structures of about uniform width. The anterior end is produced into a snout. The small birth pore is located a little behind the snout. Brown and orange pigments give these sporocysts their characteristic colour.

DISCUSSION

In the two new strigeid cercariæ described here, there is rather a close structural resemblance. The body spines have the same general arrangement, the penetration glands have the same number and position and the digestive and excretory systems are strikingly similar. The tail-stems are alike except in the number of caudal bodies. These characters indicate their close relationships to one another. As described above, *C. soraonensis*, n. sp. can be easily distinguished by having two pairs of penetration glands behind ventral sucker, four pairs of flame cells in body, six pairs of caudal bodies in tail, digestive cæca reaching posterior end of body, and no eye spots. *C. kumari*, n. sp. has six pairs of flame cells in the body and two pairs in the tail as in the former species and there are 20 pairs of caudal bodies. Sensory hairs are present on the tail in both the forms. The two species resemble very closely *Cercaria* C. Szidat, 1924; *Cercaria flexicauda*, *C. laruei*, *C. modicella*, *C. longifurca* Cort and Brooks (1928); *C. yogena* Cort and Brackett, 1937; *C. walloonii* and *C. scudderii* Olivier, 1941 in many respects.

Cort and Brooks on the basis of striking similarities in the excretory system considered *C. flexicauda*, *C. modicella* and *C. laruei* to belong either

to the genus *Proalaria* or closely related genera and from experimental evidences stated that their metacercariæ are of *Diplostomulum* type that develop in the eyes of fishes. They also observed that these fish penetrating cercariæ have the habit of hanging quietly for most part of their life. To the above group they also included *Cercaria C.* Szidat, 1924 and *Cercaria chrysenterica* Miller, 1923.

The researches of Szidat (1924 a, b) and Van Haitsma (1931) have shown that *Cercaria C.* and *Cercaria flexicaudum* develop into *Diplostomum spathacium* (Rud., 1819) and *Diplostomum flexicaudum* (Cort and Brooks, 1928) respectively. The life-cycle of another species of the Genus *Diplostomum*, *D. micradenum* (Cort and Brackett, 1938) has been elucidated by Van Haitsma (1941). The cercariæ as observed by him, penetrate tadpoles of *Rana pipiens* and *Bufo americanus* and develop into *Diplostomulum* type of metacercariæ, the adults developing in Domestic pigeons. Except slight difference in the location of the anterior pairs of penetration gland which are at the anterior margin of the acetabulum as shown in their figure, there is every similarity to the cercariæ of the above two species.

These studies indicate that strigeid cercariæ with body spines in transverse rows, long and wide digestive cæca reaching posterior end of body, generally four penetration glands back of ventral sucker, two pairs of flame cells in the tail, large number of caudal bodies and sensory hairs and without eye spots and excretory commissure in body should be considered to belong to the Genus *Diplostomum*. In addition to *Cercaria C.* Szidat, 1924: *C. flexicaudum* Cort and Brooks, 1928 and *Cercaria micradenum* Cort and Brackett, 1938, the other cercariæ which show the above group character are: *C. laruei*, *C. modicella*, *C. yegena*, *C. scudderii*, *C. chrysenterica*, *C. soraonensis*, n. sp. and *C. kumari*, n. sp.

ACKNOWLEDGEMENT

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STUDIES ON A NEW SPECIES OF SCHISTOSOME
CERCARIA FROM *LYMNÆA LUTEOLA* f.
AUSTRALIS

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INTRODUCTION

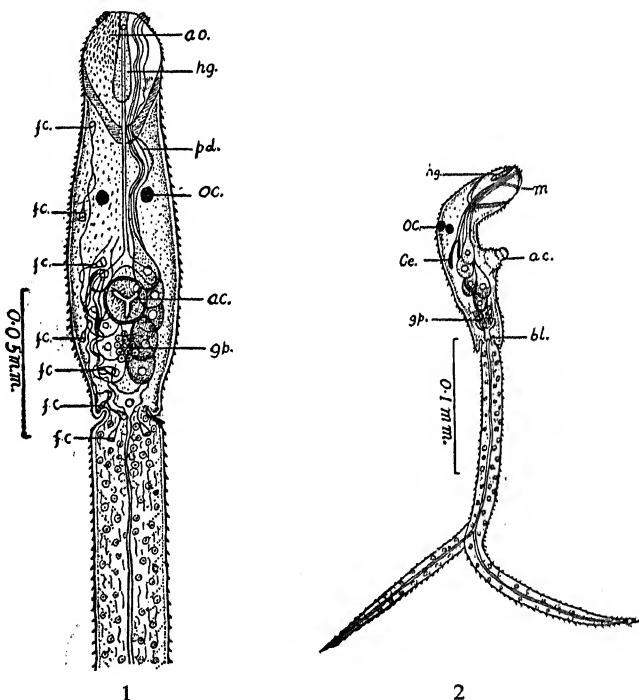
APHARYNGEAL, brevifurcate distome cercariæ were observed to come out of two specimens of *Lymnaea luteola* f. *australis* collected from a pond near village Rithaian about 30 miles east of Allahabad in December 1952. The cercariæ being the etiological agent involved in cases of "Swimmers itch" could be assigned to none of the previous species and has been described here as *Cercaria biocellata*, n. sp. The cercaria is characteristic of the avian schistosomes and in general resembles *Cercaria bombayensis* no. 19 Soparkar, 1921; cercariæ of *Trichobilharzia ocellata* (La Valette, 1853) Brumpt, 1931; *T. stagnicolæ* (Talbott, 1936) and *T. physellæ* (Talbott, 1936) but seems to be very closely related to the cercariæ of *Gigantobilharzia gyrauli* (Brackett, 1940) and *Austrobilharzia variglandis* (Miller and Northup, 1926) Penner, 1953.

The cercariæ of the avian schistosomes differ from the cercariæ of the human schistosomes in having much more elongated bodies, pigmented eye spots and furcæ somewhat longer than one half the tail-stem. Soparkar (1921) suggested that *Cercaria bombayensis* no. 19 "belong probably to the Bilharziella Group of Schistosomes". Miller (1926) while presenting an account of the Elvæ Group of apharyngeal, brevifurcate distome cercariæ in which he included *Cercaria bombayensis* no. 19 along with *C. elvæ*, *C. ocellata* and *C. gigantea* did not support Soparkar's above view in the absence of any evidence. However, the prediction made by Soparkar was confirmed when McMullen and Beaver (1945) discovered the life-cycle of *C. elvæ* and reported that it is the larval stage of *Trichobilharzia ocellata*. Cort (1928) reported that a severe dermatitis of man is caused by the larvæ of nonhuman schistosomes and this was followed by discoveries from Europe and other countries where outbreaks of "swimmers itch" was recognized. Since Stunkard and Hinchliffe (1952) have reviewed the literature on the avian schistosomes no account is given here.

Cercaria biocellata, n. sp.

After emergence from the snail host cercariæ swim vigorously in water with the help of the tail-stem. During propagation, the tail-stem oscillates from side to side due to contraction of its diagonal muscles and the furcæ generally remain at right angles to the tail-stem. There are two stationary nodes during movement, one at the region of the ventral sucker and the other a short distance anterior to the furcæ. Cercariæ swim upward and generally accumulate near the surface film of water, where they lie almost motionless with tail well extended and in line with the body, the furcæ being held at right angles to the tail. When the water is disturbed, they attach to the walls of the container and also adhere to the inner surface when picked up in a pipette. The cercariæ have a tendency to attach to the bottom of the container.

Measurements of living specimens varies with the contraction and extension of the body, tail-stem and furcæ. The body during maximum



TEXT-FIG. 1. Cercaria showing body and proximal portion of the tail.

TEXT-FIG. 2. Cercaria showing proportions of body, tail and furcæ.

ac., acetabulum; *ao.*, anterior organ; *bl.*, bladder; *ce.*, digestive cæcum; *fc.*, flame cell; *gp.*, genital primordium; *hg.*, head gland; *oc.*, eye spot; *pd.*, ducts of penetration glands;

extension measures $0\cdot325$ mm. $\times 0\cdot065$ mm. and $0\cdot195$ mm. $\times 0\cdot091$ mm. during greatest contraction. The tail-stem measures $0\cdot39$ mm. and $0\cdot28$ mm. during elongation and contraction respectively. Cercariæ killed in 10% hot formalin are well extended and uniform in size and when measured have body $0\cdot2$ mm. $-0\cdot24$ mm. (average $0\cdot22$ mm.) long; $0\cdot05$ mm. $-0\cdot06$ mm. (av. $0\cdot06$ mm.) wide; tail-stem $0\cdot35$ mm. $-0\cdot39$ mm. (av. $0\cdot36$ mm.) long; $0\cdot032$ mm. $-0\cdot039$ mm. wide tapering from base to tip. The furcæ measure $0\cdot24$ mm. $-0\cdot25$ mm. (av. $0\cdot24$ mm.) long and are provided with a group of long spines at the tips. The body, tail-stem and furcæ are covered with short spines curved at their tips. They are uniformly distributed and point backward. The anterior end of body is provided with short dense spines extending back upto half the level of the anterior penetration organ.

The dark pigmented eyes are located over the commissure of the nervous system and have a concavity in the centre provided with a lens. The acetabulum is strong, muscular, protrusible and retractile. Its cavity is Y-shaped and provided with two rows of short strong spines projecting from the surface. It measures $0\cdot04$ mm. $-0\cdot06$ mm. (av. $0\cdot049$ mm.) in diameter, and is behind the middle of body.

The anterior penetration organ $0\cdot08$ mm. $-0\cdot09$ mm. (av. $0\cdot08$ mm.) long and $0\cdot05-0\cdot06$ mm. (av. $0\cdot05$ mm.) broad is divided into an anterior and a posterior portion, the latter being muscular. The centre of the anterior organ is occupied by a head gland and on each side of this run the penetration gland ducts.

The œsophagus is narrow extending posteriorly upto the level of the eye spots; the intestinal cæca diverging at the level of the first pair of penetration glands and terminating at the level of the acetabulum. Behind the eye spots the body is occupied by five pairs of penetration glands in actively emerged cercariæ but six pairs in cercariæ obtained from crushed snails, the first pair is emptied during emergence. The first and second pairs lie anterior and dorsal to the acetabulum, the fourth, fifth and sixth pairs are behind the ventral sucker, the fourth and sixth ventral and the fifth dorsal. The cytoplasm of the anterior three pairs is coarsely granular and that of the posterior three pairs is finely granular. The ducts of these glands as shown in Fig. 2 enter the anterior organ ventral and anterior to the muscular portion and open separately at its tip through hollow conical spines.

The excretory system has six pairs of flame cells in the body and a pair at the base of the tail-stem (Fig. 2). The three anterior pairs of flame cells are connected by capillaries to the anterior collecting ducts. The posterior collecting duct of either side after receiving capillaries from three flame cells

in the posterior region of body ends in a single flame cell in the tail. There are two ciliary areas in the main ducts. The excretory bladder is small and located at the junction of the body and tail-stem. The caudal excretory duct originates from the posterior end of the bladder through an 'Islet Aperture' and after traversing the tail-stem forks at the distal end, the resulting tubes open at the tips of furcae through bladder-like enlargements surrounded by groups of large spines.

The genital primordium is represented by a mass of small rounded cells with clear nuclei situated in front of the excretory bladder and ventral to the posterior pairs of penetration glands.

The daughter sporocysts of *C. biocellata*, n. sp. occur in tangled masses embedded in the liver and attached to each other by their thin walls. The sporocysts may be cylindrical, pyriform, or fusiform and measure 0·6 mm. 0·9 mm. in length and 0·2 mm.-0·3 mm. in breadth. They are pointed at one end containing the birth pore and canal through which cercariæ emerge.

Large number of cercariæ from two snails out of 60 collected were used to infect two pigeons through oral as well as cutaneous routes. The two birds when examined after about three months were found to be free from any parasites. It was probably on account of the fact that pigeons were not the proper host of the parasite. Further experiments could not be planned on account of non-availability of infected mollusks.

DISCUSSION

The morphological features of *C. biocellata*, n. sp. show that it is an apharyngeal, brevifurcate, distome cercaria resembling several species of avian schistosomes. The cercaria seems to be closely related to *Cercaria bombayensis* no. 19 Soparkar, 1921 in many respects but differs in having a smaller size and five pairs of penetration glands instead of four, the number of flame cells being equal in the two forms.

The cercariæ of *Trichobilharzia ocellata* (La Valette, 1853) Brumpt, 1931; *T. stagnicola* (Talbott, 1936) and *T. physellæ* (Talbott, 1936), show striking similarities to the new form. However, the measurements of various parts, ciliary areas in the main excretory ducts of body, nature of the oral apparatus containing the head gland and many other minor differences in the new form can be easily recognised. The cercaria of *Gigantobilharzia gyrauli* (Brackett, 1940) has the same number and arrangement of penetration glands and flame cells but differs from the new form in the structure of the acetabulum and the anterior organ. In *C. biocellata* the acetabulum

has a Y-shaped opening with two rows of spines, a head gland in the anterior organ and the ducts of penetration glands open through hollow spines.

The cercaria of *Austrobilharzia variglandis* (Miller and Northup, 1926) Penner, 1953 as described by Stunkard and Hinchliffe (1952) and George, W. T. C. Chu and Charles E. Cutress (1954) from Atlantic and Hawaiian coasts respectively and *Cercaria biocellata* n. sp. have many features in common. Both the species resemble one another in swimming and locomotory activities, attach by the acetabulum, have same number of flame cells and penetration glands and also spination of body, tail and furcæ is similar in the two forms. But the anterior pairs of Penetration glands show coarse granules in the new form which in the former are finely granular. There is no mention of ciliary areas in the main ducts, a head gland, and hollow conical spines capping the opening of the penetration gland ducts in the cercaria of *Austrobilharzia variglandis*. The size of tail and furcæ as compared to that of body is longer in *C. biocellata* than in *A. variglandis*.

The proportions of body, tail and furcæ; their spination morphology of the anterior organ and the acetabulum; presence of a head gland; ciliary areas in the main ducts; the number, nature and arrangement of penetration glands are the characters which distinguish *Cercaria biocellata*, n. sp. from other schistosome cercariæ.

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